Precipitation Estimates for the Tropical South Pacific
During FGGE, 10-18 January 1979

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1. INTRODUCTION

During the twelve month period beginning
1 December 1978 several special observing systems
were linked together to form a comprehensive data
gathering system, the Global Weather Experiment
(GWE), or FGGE. This paper utilizes Level III-b
ECMWF analyses taken during FGGE, 10-18 January
1979, and compares estimates of precipitation,
obtained by various methods to those derived from
IR satellite brightness. Several methods can be
employed to estimate precipitation: (1) direct
surface observations; (2) upper air observations
to compute rainfall rates as the residual of the
vertically-integrated heat or moisture budget
equation; (3) parameterization schemes designed
to account for convective and stable latent heat
release; (4) radar; and (5) satellite imagery (IR
or MW). In the present analysis, radar data were
not available. Surface observations of 24 h rain-
fall amounts at the island stations shown in Fig.
1 were examined, but meaningful patterns of pre-
cipitation were difficult to construct. Thus,
only four methods were explored further. These
are briefly described below.

The data sources used in the present analy-
ses are discussed in detail by Vincent (Mon. Wea.
Rev., 1982; Q.J.R.M.S., 1985). The main source
is a modified set of grid point analyses of hori-
zontal wind components, geopotential height,
temperature and relative humidity at 2.5° lat/lon,
originally produced by ECMWF. All variables ex-
cept relative humidity are derived from object-
ively-analyzed data. Unfortunately, values of
relative humidity appear in their original form
and are based on first guess 6 h forecast infor-
mation. The latter fact has an important bearing
on some of our precipitation estimates.

The four methods used to estimate precipi-
tation in this study are the moisture budget re-
sidual technique, the heat budget residual tech-
nique, a Kuo-type parameterization scheme and an
IR satellite imagery method. The vertically-
integrated moisture budget equation can be
written as:

$$\frac{L}{g}\int\left(\frac{\partial q}{\partial t} + \vec{V}\cdot\nabla q + \omega\frac{\partial q}{\partial p}\right) dp = E-P \quad (1)$$

Distributions of each term in (1) have been ana-
lyzed for 12 h periods, with P as the residual,
for the area shown in Fig. 1. Evaporation was
computed using the Bulk Aerodynamic Method and a
set of subjectively-analyzed variables based on
island station and mobile ship and drifting buoy
data. Sea surface temperatures were obtained
from polar orbiting satellite measurements.

The vertically-integrated heat budget equa-
tion can be written as:

$$c_p\int\left\{\frac{\partial T}{\partial t} + \vec{V}\cdot\nabla T + \omega\left(\frac{\partial T}{\partial p} - \frac{R_d T}{c_p p}\right)\right\}dp = \int\frac{dh}{dt} dp \quad (2)$$

Presently, we are calculating all terms on the
left side (2), but these results are not yet
available. The residual of (2) contains net rad-
iation, latent heat release and sensible heat ex-
change with the underlying surface. We plan to
use the Bulk Aerodynamic Method to estimate
sensible heat exchange. Vertical profiles of
net radiation, which normally are much smaller
than latent heat release in active convection
regions, will be based on those given in Acker-
man and Cox (Mon. Wea. Rev., 1981). Thus,
vertically-integrated latent heat release (i.e.,
precipitation) will be computed as the residual.

The third method employed is a Kuo-type con-
vective parameterization scheme together with an
account of stable latent heat. This technique
has been used by several investigators and the
version used herein is described by Edmon and
Vincent (Mon. Wea. Rev., 1976). The moisture
storage, b, is assumed equal to zero.

The final method employed is based on en-
hanced IR satellite imagery. A third-order
polynomial of GOES IR black body temperature,
T_{BB}, was used to infer an instantaneous rainfall
rate. Three hourly, 16 km resolution imagery,
was used to generate rain rates which were then
averaged over 12 h periods. These 12 h rain
rates, when averaged over areas $\sim 10^4$ to 10^5
km^2, should have RMS errors of 50-60%. A de-
tailed description of this procedure and its
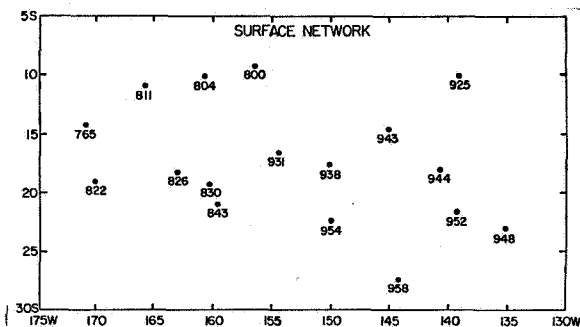error characteristics is given by Robertson
(this preprint).

Fig. 1. Locations of island stations used in
surface analyses; area used to compute
averages depicted in Fig. 3.

2. PRELIMINARY RESULTS AND FUTURE WORK

Figure 2 shows analyses of precipitation rates derived from satellite measurements for the SPCZ region for two 12 h periods. The earlier period shows two areas of heavy precipitation, one near 15°S, 160°W and the other near 20°S, 150°W. Each area is located in close proximity to a cyclone. The location of a third cyclone is also shown in Fig. 2. Cyclone development and propagation along the SPCZ is a common occurrence. Vincent (Q.J.R.M.S., 1985) gives an account of the life cycles of the three cyclones shown in Fig. 2. The later period shown in Fig. 2 was selected because the area-averaged value of P for the region was a maximum.

In order to compare the satellite-derived estimates to those from two other methods (Kuo-type and moisture budget) area averages for each method were obtained for the region bounded by 7.5°S, 135.0°W, 27.5°S and 170.0°W. This region contains the most active portion of the SPCZ during the period of investigation. Results are shown in Fig. 3. As noted above, the satellite-derived values show a peak during the middle of the period examined. In general, values derived from the Kuo-type parameterization scheme are greater than those derived from satellite measurements, while those derived from the moisture budget are less. The time-averaged values for the 7-day period shown are 0.74, 1.02 and 0.51 mm h^{-1} by the satellite, Kuo and moisture budget techniques. It is believed that the Kuo method applied in this study yields an overestimate since the moisture storage is assumed to be zero. Also, there is some question concerning the accuracy of the moisture convergence term in the Kuo scheme since humidity values in the ECMWF data set were not observed, but rather were derived from 6 h forecasts. This latter fact appears to have caused an even greater problem in the computation of precipitation rates by the moisture budget. Those precipitation estimates depended on local rates of change of vertically-integrated specific humidity (precipitable water), in addition to moisture advection; thus, it would seem that they are the least accurate of the three methods attempted to date. Evidence of our lack of confidence in the moisture budget estimates is apparent in Fig. 3 which shows an irregular pattern of precipitation with time. An examination of the time series of each of the terms in (1) revealed that the local rate of change term was primarily responsible for the trend and irregularity of the precipitation curve shown in Fig. 3. It would appear, therefore, that any method which relies heavily on ECMWF humidity values is suspect.

An alternative approach for estimating precipitation is to use the heat budget, i.e., Eq. (2). Except for net radiation, values of terms in (2) can be computed solely from analyzed variables in the ECMWF data set. Currently, we are applying this technique and plan to report on our findings at the conference. In the future we plan to apply the various methods described above to other data sets (e.g., a recently-obtained set of GLAS analyses and a revised set of ECMWF analyses, with corrected humidity values).
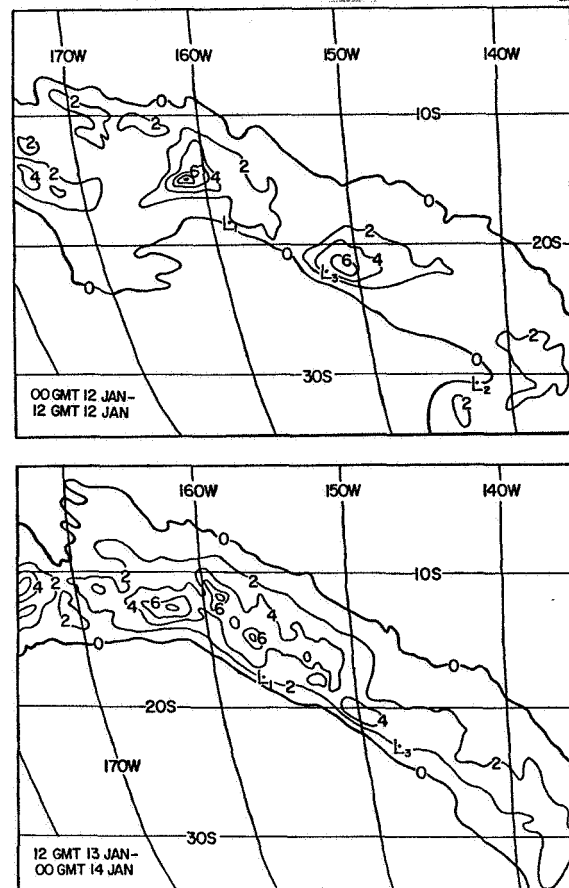

Fig. 2. Precipitation rates (mm h^{-1}) calculated from IR black body temperatures derived from satellite measurements. Positions of three cyclones also noted.
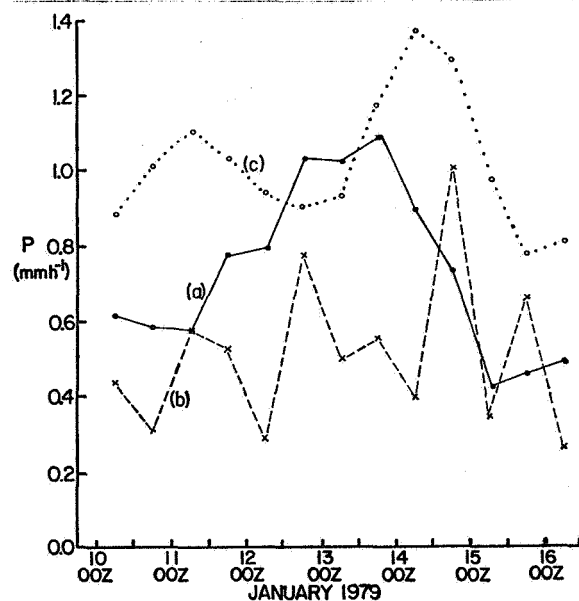

Fig. 3. Average 12 h precipitation rates (mm h^{-1}) for area depicted in Fig. 1 derived from (a) satellite measurements (solid), (b) moisture budget (dashed), and (c) Kuo-type parameterization (dotted).